DOCUMENT RESUME

ED 258 828 SE 045 824

AUTHOR Baldwin, Cynthia A.
TITLE Asbestos in Colorado Schools.
PUB DATE 81
NOTE 80p.; Master's Thesis, Colorado State University.
PUB TYPE Dissertations/Theses - Master Theses (042) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS *Asbestos; *Construction Materials; Elementary Secondary Education; *Hazardous Materials; Physical Health; *School Buildings; School Surveys
IDENTIFIERS *Colorado

ABSTRACT

This study determined, by means of a random sample, how many of Colorado's public schools have asbestos materials and estimated the potential risk of exposure presented by these materials. Forty-one schools were surveyed. Bulk samples of possible asbestos materials were collected and analyzed using the K-squared Asbestos Screening Test to eliminate samples which did not contain asbestos. Positive samples were analyzed by an accredited laboratory using polarized light microscopy. The risk of potential exposure presented by these materials was assessed for each sampling site. One hundred thirteen samples were collected. Only 10.6 percent of the samples were negative for the K-squared Test. Of the 101 positive samples, 56 actually contained one or more forms of asbestos. Twelve samples were from sprayed material, the remaining 44 were from other materials. Of the 41 schools sampled, 76 percent had asbestos materials in one or more locations. The values for the exposure potential ranged from very low to very high, with the majority presenting high exposure potentials. It is estimated from these results that from 63 percent to 89 percent of the public schools in Colorado may have asbestos materials which present potentially serious hazards to individuals using these facilities. (Author/JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED258828

MICROFILMED FROM
BEST AVAILABLE COPY

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)
✓ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

THESIS

ASBESTOS IN COLORADO SCHOOLS

Submitted by

Cynthia A. Baldwin

Department of Microbiology

In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall, 1981

SE 045 824

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Hans H. Johnson
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

ABSTRACT OF THESIS

ASBESTOS IN COLORADO SCHOOLS

The use of asbestos in building construction, especially in friable forms, was common from 1946 to 1973. Deterioration of these friable materials due to aging, accidental or capricious contact or maintenance activities may result in the release of asbestos fibers to the environment. It is well documented that exposure to low levels of airborne asbestos fibers may result in mesothelioma after a long latency period. For this reason, the possibility that children may be exposed to airborne asbestos in their schools is of increasing concern. The intent of this study was to determine, by means of a random sample, how many of Colorado's public schools have asbestos materials and to estimate the potential risk of exposure presented by these materials.

Forty-one schools were surveyed. Bulk samples of possible asbestos materials were collected and analyzed using the K^2 Asbestos Screening Test to eliminate samples which did not contain asbestos. Positive samples were analyzed by an accredited laboratory using polarized light microscopy. The risk of potential exposure presented by these materials was assessed for each sampling site.

One hundred and thirteen samples were collected. Only 10.6% of the samples were negative for the K^2 Test. Of the 101 positive samples, 56 actually contained one or more

forms of asbestos. Twelve samples were from sprayed material, the remaining 44 were from other materials. Of the 41 schools sampled, 76% had asbestos materials in one or more locations. The values for the exposure potential ranged from very low to very high, with the majority presenting high exposure potentials.

It is estimated from these results that from 63% to 89% of the public schools in Colorado may have asbestos materials that present potentially serious hazards, not only to the children in those schools, but also the teachers and staff and to members of the community who use the school buildings after regular school hours.

It is important that school administrators be aware of the location and condition of these substances in their schools and the options available for dealing with them. The decision to undertake some corrective action (i.e., removal, encapsulation or enclosure) must be carefully considered for each situation. Potential exposure values should be used together with advice from an expert skilled in dealing with asbestos materials to select the appropriate course of action. It is strongly recommended that this detection program be extended to include the remainder of the public schools in the state as well as the private schools.

Cynthia A. Baldwin
Microbiology Department
Colorado State University
Fort Collins, Colorado 80523
Fall, 1981

TABLE OF CONTENTS

Chapter		Page
1	Introduction	1
2	Literature Review	6
3	Purpose and Scope	22
4	Materials and Methods	24
	Study Design	24
	Selection of Schools	24
	Communication with the Appropriate People	29
	Survey the Selected Schools	30
	Bulk Sample Collection	32
	Analysis of Bulk Samples	33
	Reporting of Results	36
5	Results and Discussion	38
6	Summary	54
	Literature Cited	60
	Appendix A	65
	Sample Collection Data Form	66
	General Data Form	67
	An Evaluation Aid in Assessing Potential Asbestos Exposure	70

LIST OF FIGURES

Figure		Page
1	Colcrado Department of Education Regions . .	27
2	Sprayed-on asbestos material damaged by water.	48
3	Sprayed-on asbestos material damaged by capricious contact	48
4	Exposure potential values of areas with asbestos-containing materials in selected Colorado schools.	51

LIST OF TABLES

Table		Page
I	Colorado Schools Surveyed.	38
II	Asbestos-Containing Samples by Type of Asbestos	41
III	Schools Containing Asbestos by Region.	42
IV	Stratification of Schools by Age of Construction	43
V	Age of Construction of Areas from Which Asbestos-Containing Samples Were Obtained. .	44
VI	Stratification by Grade Level.	44
VII	Evaluation Aid for Assessing Potential Asbestos Exposure.	46

CHAPTER 1

INTRODUCTION

Asbestos has been known and used by man since before recorded history. Early man used it in pottery and the Greeks spoke of using fibers from rocks as wicks in lamps. Later, asbestos fibers were used in textiles and paper, but limited quantities of the mineral prohibited extensive production of asbestos-containing materials. The discovery and development of large deposits in Canada, South Africa and other countries in the 1800's solved that problem, and by 1953 asbestos was used in hundreds of products.[1] After World War II, the use of asbestos in sprayed-on form for thermal and acoustical insulation became common in the building industry. This practice was halted in 1973 in the U.S. because of the highly hazardous nature of that operation. Today, asbestos has by no means disappeared. It is still used in the manufacture of over 3,000 products. It is in our environment: in the air, water, food and drugs and consumer products.

The term asbestos itself is generic only. It refers to a group of naturally occurring silicate minerals that can be separated into fibers. There are two groups of minerals which can occur in fibrous form: the serpentine group (hydrated magnesium silicates) and the amphibole group (iron silicates). The only member of the serpentine group is chrysotile. The amphibole group includes amosite, anthophyllite,

crocidolite, actinolite and tremolite. In addition to silica, magnesium and iron, the composition of the fibers can include calcium, manganese, nickel, tin, sodium, potassium, aluminum and cadmium, all in highly variable amounts.

Asbestos fibers are virtually indestructible, although treatment with strong acids at high temperatures can effect structural changes, particularly in the case of chrysotile. Asbestos fibers are not flammable, but very high temperatures can cause the fibers to become brittle. The texture of the fiber varies from soft to harsh, with the softer fibers being more flexible. The fibers are extremely small in diameter, ranging from 0.02-0.4 μm, and can be quite long. The tensile strength of the fibers is quite high although it varies considerably with length and diameter. When the fibers are separated so that air is trapped between them, asbestos makes a very effective thermal and acoustical insulating material.[1]

That adverse health effects could result from the exposure to asbestos was recognized by Pliny the Younger (61-114 A.D.). However, official recognition of asbestosis as a disease did not come until about 1930.[1] Asbestosis is a diffuse, interstitial fibrosis of the lung tissue which comes about as the result of exposure to high levels of airborne asbestos. Asbestosis is characterized by reduction of lung volume and ventilatory capacity. The fibrosis is progressive and continues to develop even after exposure has ceased. While asbestosis itself is not fatal, the condition

predisposes the individual to heart failure or to death from infections, respiratory or otherwise. When the hazard of asbestosis was recognized, the amount of asbestos dust in the air began to be controlled, reducing the amount of dust available for inhalation. Unfortunately, another problem began to emerge, and in 1955 a link between respiratory cancer and asbestos was confirmed. Lung cancer caused by asbestos exposure is not very different from other pulmonary carcinomas, except that it tends to appear more commonly in the lower lobes of the lungs. The risk of developing lung cancer appears to be greatest in those workers who have moderate exposure to airborne asbestos fibers, possibly because competing causes of death cause fatalities earlier when workers are exposed to high levels of asbestos. In addition, smoking greatly increases the risk of developing lung cancer when in conjunction with asbestos exposure (perhaps to a factor of 92).[2] The latency period ranges from 20 to 40 years. Exposure to asbestos may also result in mesothelioma, cancer of the pleural and/or peritoneal membranes. Mesotheliomas are diffuse cancers that spread rapidly and are rapidly fatal. Prior to the middle of the century, the prevalence of mesothelioma in this country was quite low, so low, in fact, that an expected rate of occurrence in the population was not even calculated. However, since 1960 cases have accumulated rapidly and there is good correlation between asbestos exposure and development of the disease. Mesothelioma may develop even when exposures to asbestos are

quite low, as evidenced by the increased risk found in the family members of asbestos workers. Again, the latency period is quite long. There is also some evidence that asbestos can cause cancer at other sites in the body, including the larynx and the gastrointestinal system (esophagus, stomach, colon and rectum).

It is the low levels of asbestos fibers that may be found in buildings containing asbestos that is of more and more concern. Schools containing asbestos may present an especially significant hazard to America's 50 million school children. Studies done in some states have indicated that levels of airborne asbestos were usually quite low in schools, but the number of years that a child is in school coupled with the long potential lifespan ahead of the child and the fact that many individuals begin to smoke at an early age, may result in a continuing rise in the rates of lung cancer and mesothelioma in the general population in the future.

Although school children appear to be the primary group at risk, teachers and staff may also be exposed. Of this group, probably the maintenance staff would have the greatest risk as a result of being exposed to intermittent high levels of fibers in the course of maintaining the school building.

There is a need to identify asbestos-containing materials in school buildings and evaluate the condition of those materials. Sources of asbestos in a building may include

pipe lagging, ceiling tiles, boiler jackets, floor tiles and sprayed-on materials on ceilings and walls. Of these, materials that are friable or easily crumbled are of greatest concern. Sprayed-on materials are usually quite friable and thus cause the most concern since they may be subject to damage in a number of ways. Further, once the fibers are in the environment of the school, they remain airborne for long periods of time, are most difficult to remove and are easily reentrained in the air.

In 1979, the Environmental Protection Agency (EPA) instituted a voluntary inspection and control program. Unfortunately, the response to this program was poor, so in 1980 EPA and the U.S. Department of Education separately proposed similar regulations requiring that detection programs be carried out in schools across the nation. As of August, 1981, neither of these regulations were adopted.

This study was designed to determine the extent of use, present condition and potential for fiber release of asbestos-containing materials in Colorado schools. The results provided information regarding the specific schools in the study for the use of the Colorado Department of Education. In addition, the results may be used as a model for developing a detection program for the remainder of the state.

CHAPTER 2

LITERATURE REVIEW

The word asbestos has different meanings to different people. To the mineralogist, asbestos is a generic name for a group of naturally occurring hydrated mineral silicates of the amphibole or serpentine series. These silicates are characterized by fibers (amphiboles) or bundles of fine single crystal fibrils (serpentine). Typically, the length-to-width ratio of these fibers is of the order of 100 or more. Chrysotile, crocidolite, amosite and the fibrous forms of anthophyllite, tremolite and actinolite are included in this definition.[4] To industry, asbestos is a valuable mineral which is flexible enough to be woven into fabrics and virtually indestructible, providing protection against weather, corrosion, fire, heat, cold, acid, alkalies, electricity, noise, energy losses, vibration, accident, frost, bacteria, dust and vermin.[1] To school officials across this country, asbestos presents a serious problem with which it may be difficult to deal.[4-6]

Asbestos was used as early as the Stone Age, when it was incorporated into pottery. The Greeks used asbestos for lamp wicks, and a Greek doctor used it as acoustic insulation as early as 28 B.C. The Egyptians used asbestos cloth. Despite these early uses, asbestos was regarded as a curiosity and the subject of witchcraft until the end of the 17th century.[1,7] The discovery of large deposits of this

versatile mineral in various parts of the world (Canada, South Africa, Italy, U.S.S.R., U.S. and Rhodesia) in the latter part of the 19th century made possible the commercial production and use of asbestos products. By 1953, asbestos was used in hundreds of products.[1] In 1981, asbestos was used in some 3,000 commercial applications, including potholders, brake linings and construction materials.[8]

Asbestos-containing materials have been widely used in building construction. Asbestos was cheap and could be applied quickly, consequently, it was popular as a coating to cover irregular or unattractive surfaces,[9] and it was applied extensively to steelwork to retard structural collapse during fire and to overhead surfaces for the purposes of thermal and acoustic insulation and condensation control.[10,11] It also served as a binder to keep plaster adhering to ceilings.[9] The asbestos content of these materials varied from trace amounts to nearly 100%. During the period immediately after World War II until 1973, the usual method of application was by spraying, although it was also trowelled onto overhead surfaces, steel beams, ceilings, walls, furnaces and pipes.[6,9,11] Other uses of asbestos-containing materials in buildings include pipe lagging, cement products, plaster, fireproof textiles and vinyl floor tiles.[12]

The pathogenicity of asbestos was remarked upon by Pliny the Younger (61-114 A.D.) when he noted that slaves who worked with asbestos became sick. It was not until 1930,

however, that asbestosis was officially recognized as a disease entity.[1] Asbestosis is a diffuse, interstitial fibrosis of lung parenchyma which is the result of exposure to high concentrations of asbestos dust.[1,13]

The first report of an association between asbestos and bronchogenic carcinoma was in 1935.[1] The evidence to support the link between lung cancer and asbestos is now overwhelming and it is evident that different degrees of risk exist among different occupationally exposed groups, with the risk clearly related to intensity of past exposure and the risk of asbestosis.[13] It is also clear that the individual who smokes and is exposed to asbestos has a much greater risk of developing lung cancer. This elevated risk may be 30-92 times the risk of a person who neither smokes nor is exposed to asbestos.[2,3,9,14]

The relationship between mesothelioma and asbestos is also well established. Mesothelioma is a malignant tumor of the lining of the thoracic (pleural) or abdominal (peritoneal) cavities.[15] The occurrence of this tumor was thought to be exceptionally rare until the 1950's.[1,16] Since then, however, the incidence has been increasing,[1] and studies in Britain indicate that the true incidence may be underreported due to misdiagnosis.[17] The latency period between exposure to asbestos and onset of the disease is commonly over 30 years,[13] with a range of 20-40 years.[18,19] Unfortunately, mesothelioma can result from nonoccupational exposures as well as occupational ones (including incidental exposures in

occupations not commonly associated with asbestos). Nonoccupational exposures may be domestic, neighborhood or urban.[20] Domestic exposures may occur when a member of the household is an asbestos worker,[17,21-26] or when people live in houses containing asbestos materials, i.e., pipe lagging or insulation.[27] Neighborhood exposures may occur among residents in the vicinity of asbestos mines, mills and factories,[19,23,24,26-31] or among people who live and work along roads on which asbestos is trucked.[3,27] Urban exposures may be the result of emissions from brake linings, factories and/or construction work.[3,26,31,32] Occupations in which incidental exposure to asbestos may occur include shipyard workers, sheetmetal workers,[3] workers in various building construction trades (pipefitters, welders, electricians, plumbers, carpenters and others who may have been on construction sites while fireproofing materials containing asbestos were being sprayed)[26,30,33] and building maintenance workers.[6] Although the level of exposure is not known in most cases, the association between apparently low levels of exposure to asbestos for relatively brief periods in the past is documented.[20,34,35] It must also be noted that the dose-response relationship between asbestos and mesothelioma is unclear, but studies suggest that the incidence of the disease is not related simply to the magnitude of dust exposure, i.e., personal factors are important as well.[22,23]

Other health effects which may result from exposure to asbestos dust are nonmalignant pleural changes (also known

as pleural asbestosis). These include pleural thickening, pleural effusion, hyaline plaques and calcified plaques. They may occur individually or in combination.[1] While these kinds of changes are not proof-positive of exposure to asbestos,[13] a number of studies have suggested an association between pleural changes and asbestos exposure.[25,36-38] When these pleural changes are due to asbestos, the possibility that other tissue changes might occur exists and, in at least some environmental circumstances, mesothelioma could occur.[39]

The finding of asbestos (or ferruginous) bodies and uncoated asbestos fibers in lung tissue of a high proportion of people is evidence of nonoccupational asbestos exposure.[16,36,39] Studies in Miami and Cape Town, South Africa produced very similar results: asbestos bodies in 27.2% and 26.4% respectively. Each study examined smears from 500 lungs.[40,41] Another study in New York of 3,000 consecutive autopsies found asbestos bodies in 48.3% of the lung specimens.[42] Although based on limited data, there is some evidence to indicate an association of high ferruginous body counts with carcinoma of the lung in patients without known asbestos exposure.[43] Additional studies of lung tissue have found uncoated asbestos fibers as well. In the New York study, fibers less than 1.0 μm in diameter were found in 1,038 of 3,000 specimens. Examination of 28 of these specimens identified the fibers as chrysotile.[42] It appears from this and other studies that inhabitants of most

industrial cities may acquire up to 20,000 fibers/gram of lung tissue without being occupationaly exposed or having contact with a family member who works with asbestos.[31,44] Hence, asbestos can be considered almost a normal postmortem finding in the lungs of urban dwellers.[7] Because of its indestructibility, the half-life of asbestos could be described as an infinity of years. It is possible that the carcinogenic potential of asbestos is determined as much by the duration of exposure as by the amount,[41] and, for the exposed individual, the duration is the remainder of his or her life.[9,34]

It should also be noted that accumulated human health data indicate that all commercial types of asbestos are capable of producing significant disease.[34,45] Furthermore, no safe level of asbestos exposure has been determined.[12]

Currently, the exposure of children to asbestos in school buildings is of great concern. This is an especially worrisome problem because the long latency period for development of lung cancer and mesothelioma means that this population may be in early middle age before either of these diseases would develop. This greatly complicates the estimation of the risk involved and the identification of exposure sources.[9] Children may be more susceptible to the ill effects of asbestos for a number of reasons: 1) they have a higher breathing rate resulting in a higher rate of exchange and a relatively greater volume of air exchanged than adults;[46,47] 2) more intense physical activity also

increases the rate of air exchange in the lungs; 3) vigorous play activity may stir up settled dust; and 4) exercise and blockage of nasal passageways (frequent due to nasal or bronchial infections) may cause mouth breathing resulting in less effective natural filtering. All these factors may result in more rapid migration of inhaled fibers to pleural surfaces in young and active individuals than in older persons. Children may also be especially vulnerable due to their rapid growth rate.[48,49] Large numbers of students may be exposed at the same time and they are in school daily for most of the year. In addition, school children are very active and asbestos-containing materials may be damaged during school activities or as the result of capricious behavior. Cigarette smoking, common among school children, is an additional problem.[12]

The friable types of asbestos-containing materials present the immediate hazard. Friable materials are easily crumbled, pulverized or reduced to powder in the hand. These materials may be found as sprayed surfaces (walls, ceilings, air plenums) and pipe lagging.[12] Such materials are subject to deterioration due to water damage, air currents, maintenance activities, aging, vibration and/or vandalism (primary cause, especially in schools).[9]

Contamination of the school environment by asbestos fibers occurs by three general modes: 1) fallout; 2) contact or impact; and 3) reentrainment (secondary dispersal). Fallout results in continuous, low level and long-lived fiber

dispersal. It may occur without actual physical disruption and may simply be a function of degradation of the adhesive. Variations in fallout rate are due to structure vibration, humidity variations, air movement from heating and ventilating equipment and air turbulence and vibration caused by human activity. Contact contamination depends upon the accessibility of the material and the probability of contact occurring. Contact may be intentional and unavoidable during maintenance activities, accidental during routine activity or deliberate through vandalism. Contamination by contact may result in extremely high fiber levels and damage may be extensive. Finally, reentrainment results in repeated contamination of the environment by resuspension of fallen fibers. Reentrainment may result in significant exposures to students and custodians.[10,50]

Once a fiber is released into the environment, it enters a downward settling phase. This phase is generally determined by the size, mass, form and axis attitude of the fiber. The range of these characteristics affects the settling velocity and, therefore, the hazard potential of the fiber. Settling velocity is strongly dependent upon fiber diameter and, to a lesser extent, fiber length. Fiber size is important in determining respirability as well. Fibers less than 3.5 μm in diameter are considered to be respirable.[36] Turbulence prolongs settling and also causes reentrainment of fallen fibers. In addition, while airborne, fibers can move laterally with air currents and contaminate

spaces which are far from the point of release.[10] In perfectly still air, fibers can remain airborne for many tens of hours. Drafts or turbulence merely prolong the length of time fibers are airborne.[9]

That asbestos-containing materials are present in schools is confirmed by the literature. In the Art and Architecture Building at Yale University, 35,000 ft^2 of exposed surface were found to be covered with friable asbestos-containing material. Gradual deterioration of these surfaces due to air currents, ventilation leaks, vibration, accidental and capricious contact, maintenance work and installation of fixtures or partitions resulted in measurable levels of airborne asbestos.[51]

In New Jersey, school administrators were asked to report the presence and condition of asbestos surfaces in all school buildings within the state. The responses indicated that 265 of approximately 2,400 schools in the state had what was considered to be asbestos materials. To confirm this information, 48 schools were selected at random from those schools which were reported to have asbestos surfacing. The schools were visited to obtain bulk samples of the material and to make a visual inspection for damage or deterioration. X-ray analysis of the samples confirmed the presence of asbestos in 97% of those schools in which school administrators believed that the sprayed material contained asbestos. Furthermore, two-thirds of those schools with asbestos surfaces had some visible evidence of damage to the

materials. A disadvantage of this study is that it did not provide information on schools in which school officials mistakenly believed that no asbestos was present. Also, many school administrators did not report the presence of asbestos materials in areas not used by students, such as boiler rooms. Even though these areas are not used by students, the possibility exists that asbestos from such sources could be dislodged and transported into student use areas.[52]

An asbestos hazard evaluation of Rhode Island schools focused on 326 public and private schools which had been built between 1950 and 1973. Again, school authorities were asked to report suspected materials. Samples were then taken by inspectors from the health department and analyzed by microscopic and petrographic methods. The level of hazard was also assessed as either potential (when the material was intact), or overt (when obvious damage had occurred). The presence of sprayed asbestos was confirmed in 8% (24) of the schools. Only four of the schools had major overt hazard situations; the other 15 schools were considered to be potential hazards.[53]

The State of Massachusetts evaluated schools built, renovated or added onto between 1946 and 1973. Identification of schools by school district personnel proved unsatisfactory due to a low response rate, so surveys for asbestos-containing materials were conducted by state personnel. In schools containing sprayed material, bulk samples were collected and health hazard indicators assessed on numerical

rating forms. The health hazard indicators included accessibility, condition, friability and presence of the material in an air plenum. The bulk samples were analyzed by at least two of the following: phase contrast microscopy, infrared spectrophotometry and electron microscopy. Air samples were also collected in each school containing sprayed asbestos. To interpret the collected data, the Ferris Index was used to reflect the degree of potential hazard from the material. This index incorporated data on accessibility, condition, friability, presence in air plenums and the percentage of asbestos in the material (used as a multiplier). In general, the higher the value, the greater the degree of potential hazard. Of 1,425 schools built, renovated or added onto during 1946-1973, positive samples were taken from 173. Two broad categories of sprayed asbestos were found: 1) fibrous types which were soft, spongy, friable, porous and lightweight; and 2) cementitious types which were less friable, denser and heavier. The Ferris Indices for the 173 schools were grouped into five value ranges, each with a different recommendation: 1) 0-4, no action (15 schools); 2) 5-9, review in two to three years (67 schools); 3) 10-15, review in one year (42 schools); 4) 16-20, either surveillance or control (no schools); and 5) 21 and over, control (49 schools). In the process of conducting this study, pipe lagging was found to present a potential hazard as well. Finally, the Asbestos Commission in Massachusetts recommended that comprehensive state-wide projects should review every

school, regardless of construction date, to determine potential health hazards associated with both pipe lagging and sprayed material.[54]

Widespread use of asbestos in schools has also been reported in New York, Indiana, Kentucky, Oklahoma and Connecticut.[46,52]

In 1979, school officials across the country were asked by the Environmental Protection Agency (EPA) to identify asbestos-containing materials in their schools and to take steps to protect students and school personnel from exposure. Guidance packages were distributed which contained both general and specific information about surveying, testing, mitigation and removal of asbestos. Also participating in the program were the Department of Health, Education and Welfare, the Occupational Safety and Health Administration and the Consumer Product Safety Commission.[5,12]

The steps in conducting an asbestos control program as outlined by EPA in this guidance document were the following:

1) inspect the school building for friable material;
2) if friable material is found, take a bulk sample of the material;
3) have the bulk sample analyzed by a laboratory to determine if asbestos is present in the sample;
4) assess the exposure potential if the material contains asbestos; and
5) take a corrective action if an exposure problem exists.[12]

A visual inspection for friable asbestos material should include all areas of the building, including student, administrative, maintenance and custodial areas. This inspection should also include spaces above suspended ceilings.

Sampling and analysis of friable material is always necessary because neither visual inspection nor checking building records establish the presence of asbestos in friable materials. A representative sample of a friable material, or a bulk sample, should be taken from the material itself, being certain to penetrate the depth of the material. Air sampling is not recommended as the standard technique does not specifically identify asbestos fibers.

Bulk samples should be analyzed by polarized light microscopy and x-ray diffraction if additional characterization is necessary. The percent of each type of asbestos present in the material should be reported.

The following factors should be considered in an exposure assessment. These factors may act singly or in combination to cause environmental contamination and exposure of building users.

1) Condition of material - indicates extent of contamination and the likelihood of future contamination.
2) Water damage - may result in release of asbestos fibers.
3) Exposed surface area - affects potential fiber fallout levels and the possibility of contact and damage.

4) Accessibility - good indicator of possible future exposure caused by contact and damage.

5) Activity and movement - combines the effects of general causes that may result in contact and damage; includes air movement, building vibration from machinery or any other source and activity levels of students or building workers.

6) Air plenum or direct air stream - undisturbed friable material in an air plenum or direct air stream presents a low potential for contaminating the building environment, however, contact and damage may occur during maintenance, repairs and renovation.

7) Friability - the more friable the material, the greater the potential for asbestos fiber release and contamination.

8) Asbestos content - with a high percentage of asbestos, there are more fibers that can be released to contaminate the building environment.

If a building contains friable materials and exposure is occurring or will likely occur, corrective action should be considered. The type of corrective action chosen should take into consideration the location of the material, its condition, function and the cost of the corrective action. The four approaches to controlling exposure are:

1) removal - material is removed and buried;

2) encapsulation - material is coated with a bonding agent called a sealant;

3) enclosure - barriers such as suspended ceilings separate the asbestos material from the building environment; or

4) deferred action or management - no action is taken; the area is inspected periodically.[12]

Friable materials can be screened quickly for asbestos using the K^2 Asbestos Screening Test. This test liberates magnesium from chrysotile and a blue-colored complex is formed; or iron is liberated from amosite or crocidolite, forming a red-colored complex. No false negative reactions have been found to occur, but false positives are possible. A positive result for either of these tests indicates that asbestos may be present and those samples should be analyzed by other methods to confirm the presence of asbestos. The magnesium test is performed first. Since calcium will also yield a positive reaction, samples may be washed with glycerin before the test to remove the calcium. If the magnesium test is negative, the sample should be tested for iron. An acid wash prior to the test to remove iron from other sources can reduce false positives.[55]

EPA recommends that friable materials be analyzed by polarized light microscopy to confirm the presence of asbestos. X-ray diffraction may be used when a second, independent analytical technique is necessary to confirm an analysis by polarized light microscopy.[12]

Although it is not known how serious health effects which might arise from exposure to airborne asbestos in schools would be, or how much of the population would be affected, we should be aware that the potential for exposure exists. Even if it is impossible to remove all asbestos-containing materials from school buildings to remove this exposure potential, it is most important to identify these substances and be aware of the possible consequences of disturbing them.

CHAPTER 3

PURPOSE AND SCOPE

The problem of asbestos in schools should be of concern to everyone. It is well-known that exposure to asbestos in the workplace may result in asbestosis or cancer (i.e., lung cancer and mesothelioma). Mesotheliomas (which have a high association to asbestos exposure) have also arisen in the families of asbestos workers and in persons who have been exposed to asbestos in the environment. This indicates that development of mesothelioma does not require an extensive exposure to asbestos fibers. It is also known that the combination of exposure to asbestos and smoking can synergistically increase the risk of lung cancer.

Asbestos was used extensively in building construction from 1946 to 1973. Of primary concern are friable materials (especially sprayed-on materials) which can easily release fibers to the environment upon impact (intentional or accidental), as a result of water damage or even through general aging of the material. The exposure of children to asbestos fibers is of special concern because of the length of life-span remaining for them, easily allowing 40 or even 50 years for lung cancer or mesothelioma to occur. A question which no one is able to answer is how many of America's 50 million school children are exposed to asbestos in their schools.

This study was developed to determine how extensively asbestos-containing materials have been used in Colorado

schools, the current condition of these materials and an estimate of the potential for fiber release from these materials.

A random sample of 41 schools was chosen for inclusion in the study. These schools were stratified by the type of school (elementary, junior high, senior high and other) and the period during which the school was constructed. Three categories for age of construction were used: pre-1946, 1946-1973 and post-1973.

The schools were then visited for the purposes of obtaining samples of materials that might contain asbestos and assessing the general condition and potential for fiber release of those materials. Sample locations included classrooms, hallways, offices, maintenance areas, gymnasiums, auditoriums, cafeterias and air plenums.

A preliminary analysis of the samples was performed using the K^2 Asbestos Screening Test. Positive samples were confirmed by an outside laboratory using polarized light microscopy and dispersion staining.

CHAPTER 4

MATERIALS AND METHODS

Study Design

The first step in the design of the study was the selection of the schools to be surveyed. Secondly, it was necessary to contact the appropriate school administrators to inform them of the study. Next, the selected schools were surveyed and bulk samples of materials which might contain asbestos were collected. The samples were analyzed to ascertain whether or not asbestos was present. Finally, the results were reported to the surveyed schools and the Colorado Department of Education.

Selection of Schools

Forty schools were to be selected for inclusion in the study. The decision was made to limit this study to the public schools in Colorado because of the limited number of schools which would be surveyed. The selection of schools was made by dividing the State of Colorado into regions, selecting school districts at random from those regions and, finally, selecting individual schools, again at random, from those school districts.

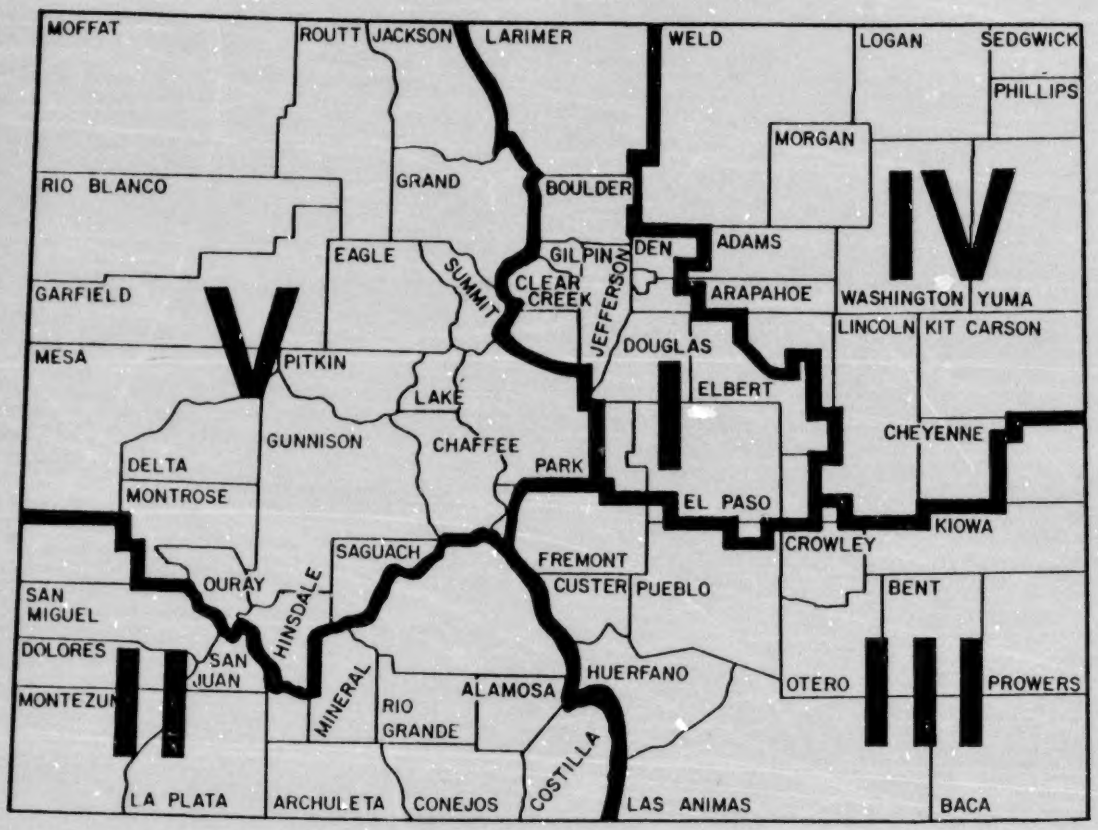
Two purposes were served by dividing the state into regions: first, to obtain a representative sample of schools from the state and, secondly, to see if there were any

geographical differences in the use of asbestos materials in school building construction in the state. Colorado is divided into five administrative and communication regions by the Department of Education (Figure 1). These regions happened to suit the aforementioned purposes very well, so they were adopted for use in this study. In addition, use of the Department of Education's own regions would have provided us with appropriate lines of communication to district school officials if such had been necessary. Of these five regions, Region I is basically urban with the largest population and, therefore, the largest number of schools. The other four regions are basically rural.

As recommended in the Massachusetts study,[54] schools of all ages of construction were included in the study. The original concept in this study was to stratify all of the Colorado schools by age of construction and dates of remodelling or additions into three groups: prior to 1946, 1946-1973 and post-1973. The purpose was to determine if there was a difference in the quantity or type of asbestos-containing materials used in each of the three periods.

An additional stratification was to be by the grade levels served at each school, i.e., elementary (primary to six), junior high (five to nine), senior high (seven to 12) and other (primary to 12). Stratification by grade level was intended to indicate differences in utilization of rooms and in levels and kinds of activity. There is some overlap between these categories because a number of different

Figure 1. Colorado Department of Education Regions.


MOFFAT
ROUTT
JACKSON
LARIMER
WELD
LOGAN
SEDGWICK
PHILLIPS
MORGAN
RIO BLANCO
GRAND
BOULDER
IV
EAGLE
SUMMIT
GILPIN
DEN
ADAMS
CLEAR CREEK
JEFFERSON
ARAPAHOE
WASHINGTON
YUMA
GARFIELD
V
LINCOLN
KIT CARSON
MESA
PITKIN
DOUGLAS
ELBERT
LAKE
CHEYENNE
GUNNISON
CHAFFEE
DELTA
PARK
MONTROSE
EL PASO
KIOWA
CROWLEY
SAGUACH
FREMONT
OURAY
CUSTER
PUEBLO
BENT
SAN MIGUEL
HINSDALE
DOLORES
SAN JUAN
HUERFANO
OTERO
PROWERS
MONTEZUMA
MINERAL
ALAMOSA
RIO GRANDE
COSTILLA
LA PLATA
ARCHULETA
CONEJOS
LAS ANIMAS
BACA

combinations of grade levels exist in Colorado. Included in the elementary school bracket were schools with grades primary to five, kindergarten to six, kindergarten only, one to four and four to six, to name a few. Junior high schools included the typical grades seven to nine as well as six to nine, five to eight, etc. Most of the senior high schools had grades nine to 12, but some had grades seven to 12, eight to 12, 10 to 12 and 11 to 12.

Information on the dates of construction and remodelling or additions was obtained from the Department of Education for about 70% of the public schools in Colorado. These data, along with the grade levels served by each school in Colorado, were entered into the computer. Attempts to randomly choose schools from these stratifications proved this method to be infeasible due to the small number of schools which could be surveyed and the large number of variables involved in the stratifications. At that point, it was decided to simply choose 40 schools at random and to then stratify those schools into the above categories.

The first step then was to randomly select districts from each of the five regions. This was done as a means of clustering the schools to reduce the amount of travelling between selected schools. The districts were chosen in such a manner that each school in the state would have an equal chance of being included in the study. Seven districts were selected based on the total number of schools in each region. This resulted in the selection of one district

from each of regions II, III, IV and V, and three districts from region I.

The schools to be surveyed from each district were chosen using random numbers. Each school in the state had been arbitrarily assigned a number when it was entered into the computer and these numbers were used in the selection process. The number of schools to be chosen from each district was proportional to the total number of schools in the region. In addition, in region I, the number of schools sampled in each of the three districts was proportional to the total number of schools in the respective district.

Communication with the Appropriate People

The next step was to apprise the appropriate people in the state of the study and to obtain permission to conduct the surveys. The State Department of Education was contacted first. With approval and support from the state level, the superintendents of the selected districts and the principals of the selected schools were notified by letter explaining the goals of the study and requesting their support and assistance in accomplishing these goals. The next contact with the district superintendents was by telephone to arrange dates for the school surveys to be conducted. The district superintendents were also asked to call a meeting of principals of selected schools, maintenance staff of the district and any other interested personnel immediately prior to the school visits. At this meeting a slide presentation was

made which was designed to educate the group about asbestos, asbestos-related illnesses, control methods and the purpose of the study.

Survey the Selected Schools

The survey consisted of a walkthrough and visual inspection and evaluation of the potential exposure hazard from possible asbestos-containing materials. The walk-through and visual inspection included all areas of the school: hallways, classrooms, gymnasiums, auditoriums, cafeterias, offices, boiler rooms, storage spaces and the spaces above lowered ceilings.

The evaluation criteria were based on the Ferris Index used by Massachusetts[54] and on the EPA guidelines for exposure assessment.[12] The evaluation was designed to reflect the potential exposure hazard that might exist by determining where asbestos materials were and their condition. Six criteria were evaluated: condition, accessibility, air movement, activity, friability and percent asbestos. *Condition* was a reflection of the degree of deterioration and/or damage of the materials. *Accessibility* was the relative ease with which asbestos-containing material may be reached or disturbed. *Air movement* reflected the degree to which asbestos fibers might accumulate at a site. *Activity* was the potential, because of room use, for damage to occur to asbestos-containing materials. *Friability* was the ease with which the materials could be broken or crumbled. Finally, *percent*

asbestos was the amount of asbestos present in the material. This was obtained later from laboratory analysis of bulk samples. In each of the categories, a number (from one to three in the first five, one to four in "percent asbestos") was assigned to reflect the exposure potential of each. The lowest number reflected the least potential while the highest number indicated the greatest exposure potential for that criterion. The total of the assessed value for each of the above criteria reflected the overall exposure potential, with higher values generally representing greater potentials for exposure. This total value could be used by the school to help determine what action, if any, should be taken. Values of six to eight would indicate that exposure was negligible or that no potential for exposure existed. In such cases no action would be necessary beyond a continuing inspection program to monitor the situation. Higher values, from nine to 19, would indicate that some corrective action (i.e., removal, encapsulation or enclosure of the material) should be considered.

The values for each of the criteria (except "percent asbestos") were recorded on a form at the time of evaluation (see Appendix A). Evaluations were made for each area from which a bulk sample was obtained.

At the time of the survey, additional information about the school was obtained (see sample form in Appendix A). This included the number of pupils in the school, the number of teachers and staff (full and part-time), building

usage (standard curricular use, extracurricular use and community and other use) and building construction data were confirmed (original construction date and dates of additions and remodelling). If available, the names and addresses of architects and contractors for original and subsequent construction were also obtained.

Bulk Sample Collection

Bulk samples were taken from all friable materials which might have contained asbestos. These included ceiling tiles, pipe lagging, sprayed materials and jackets on boilers and furnaces. As mentioned previously, the potential exposure from the materials was evaluated at the time the sample was obtained. Samples were taken by removing a portion of the material with a scalpel. The samples included all layers from the outside of the material to the substrate. Samples were placed in clean, empty 35 mm film canisters and labeled with a code corresponding to that on the evaluation form. The sampling site was noted on the form along with any additional pertinent information. All samples were taken in such a manner as to damage the materials as little as possible and in as inconspicuous a place as possible. Respirators were not worn while sampling to avoid alarming students and staff, but precautions were taken to avoid inhalation of any dust (sample container was held away from the face and a ladder was used where possible to reach the

sampling site to avoid standing directly beneath it while sampling).

Analysis of Bulk Samples

The bulk samples were first screened for the potential presence of asbestos using the K^2 Asbestos Screening Test. This is not actually a test for asbestos, but for magnesium ion released from chrysotile or the iron ion from the amphibole forms of asbestos. The test does not give false negatives, but it can yield false positives so it was necessary to confirm positive samples by another method. In addition, the K^2 Test does not provide information about the specific kind of asbestos present or the percentage of asbestos in the sample.

The K^2 Test is a colorimetric test. A positive result is obtained if a blue color appears for the magnesium test, or a red color for the iron test. The magnesium test is performed first on a portion of the bulk sample about the size of a pea. The suggested technique is to place a drop of the magnesium reagent on the sample. If a blue color appears, the sample msut be washed with glycerin and filtered to remove calcium which also yields a blue color. To reduce the amount of time involved in doing this analysis, however, this preliminary step was dropped and all samples were washed with glycerin and filtered prior to beginning the analysis. Samples which were negative for magnesium were tested for iron. A new portion of the sample was used for

the iron test. Again, a preliminary step is to place a drop of iron reagent on the sample. A red color indicated that an acid wash was required to remove iron from other sources which might interfere. This preliminary step was also dropped and all samples acid washed and filtered before testing. The steps followed in the analysis were as follows:

A. Magnesium Test

1. Glycerin wash
    a. Place a small portion of sample, about the size of a large pea, in a mortar.
    b. Crush the sample and add five drops of glycerin. Mix well with a plastic rod or spatula.
    c. Rinse the plastic rod with a small amount of distilled water into the mortar.
    d. Filter the sample through the filtration assembly consisting of a syringe attached to a Swinnex filter holder loaded with a mixed cellulose ester filter (25 mm, 0.8 µm) and a gasket.
    e. Filter with a minimum of five washings or about 50 mL of distilled water.
    f. Transfer the filter to a Teflon dish for the magnesium test.
2. Add a drop of H_3PO_4 and mix well by grinding the sample with a plastic rod.
3. Add two drops of 10 N NaOH and mix well.

4. Add five drops of magnesium reagent and stir briefly. Note any color change.
5. Add five more drops of magnesium reagent and observe the final color.
6. A blue color indicates that chrysotile may be present.
7. If the magnesium test is negative, the sample must be tested for iron.

B. Iron Test

1. Acid wash
   a. Place a small portion of the sample, about the size of a large pea, in a mortar.
   b. Crush the sample.
   c. Add five drops of concentrated acetic acid.
   d. Add five drops of concentrated sulfuric acid.
   e. Mix well.
   f. Filter the sample through a polyvinyl chloride filter (25 mm) with a minimum of five washings or about 50 mL of distilled water.
   g. Transfer the filter to a Teflon dish and proceed with the iron test.
2. Add a drop of HF solution and mix well.
3. Add five drops of iron reagent and observe the development of red color.
4. The red color indicates that amosite or crocidolite may be present.

For samples which were positive for either magnesium or iron, a portion of the sample (approximately one-half of whatever remained) was placed into another clean, empty 35 mm film canister. These were labeled clearly with the sample numbers and sent to an outside laboratory for analysis to confirm the presence of asbestos, determine the type of asbestos and estimate the precent of asbestos in the sample. The confirmatory technique used was polarized light microscopy with dispersion staining. The remaining portion of the bulk sample was retained in our laboratory for future reference if necessary.

Reporting of Results

Each school district included in the study was sent a report as soon as the results were received from the confirming laboratory. The report included the following information for each school surveyed in the district: the field sample number of each bulk sample taken, the type of material and the location from which the sample was taken, the results of the K^2 Screening Test (either positive or negative), the results from the outside laboratory (if the presence of asbestos was confirmed, the types of asbestos and their percentages were reported) and some brief comments on the condition of the material if it did indeed contain asbestos.

The results for all of the schools surveyed were reported to the Colorado Department of Education. Based on the number of schools found to have friable asbestos

materials, the range of schools in Colorado which might have asbestos was estimated (95% confidence interval). A similar calculation was made to estimate how many schools might contain sprayed-on asbestos materials.

CHAPTER 5

RESULTS AND DISCUSSION

The objective of this study was to determine how many public schools in Colorado contained friable asbestos building materials. This objective was attained by surveying a random sample of 41 schools across the state. This number represented about 3.2% of all the public schools in Colorado. Table I shows the number of schools in each of the five regions and the number of schools surveyed in each region.

Table I. Colorado Schools Surveyed

Region	Number of Schools	Number of Schools Sampled
I	714	23 (3.2%)
II	94	3 (3.2%)
III	157	6 (3.8%)
IV	142	4 (2.8%)
V	156	5 (3.2%)
TOTAL	1,263	41 (3.2%)

One hundred and thirteen samples of friable materials that possibly contained asbestos were collected from these schools. Multiple samples were taken from several schools. In three schools, no materials which might have contained asbestos were observed, therefore no samples were collected.

Preliminary screening of the 113 samples using the K^2 Test yielded negative results for only 10.6% (12) of the samples. This is considerably different from the results reported by the researchers who developed the K^2 Test where about 41% of the samples tested were negative.[55] The 101 samples which yielded positive results were sent to a laboratory accredited by the American Industrial Hygiene Association for confirmation of the presence of asbestos. Polarized light microscopy was used with dispersion staining to identify the type of asbestos in the sample. Of those, 56 (55%) actually contained asbestos. At first glance, this is very close to the results reported by the researchers where 54% of the K^2 positives were true positives. However, those results were achieved prior to the addition of the acid wash step to the iron test. With the acid wash, no false positives were observed by the researchers.[55] All of the Colorado samples which were positive by the K^2 Test for iron were acid washed, so again the results were not comparable. Part of the discrepancy in results may be attributed to difficulty in interpreting color variations. The instructions do not mention the wide variety of colors that may be obtained, including not only various shades of blue (magnesium test) and red (iron test), but also yellow, green or no color at all. The last colors were treated as negative. In addition, the test is described as one which may be used in the field. Use in the field, however, would be most difficult due to the strong acids and bases which

are used, and the associated disposal problems once the test is completed.

The types of asbestos found included chrysotile, actinolite, amosite and crocidolite. The percent of chrysotile in sprayed materials ranged from <1 to 30%. Actinolite was frequently found with chrysotile in sprayed materials, but only in small amounts, ranging from <1 to 2%. In other asbestos-containing materials, the amount of chrysotile varied from <1 to 95%. Amosite content ranged from <1 to 60% of the materials, and crocidolite was found in very small quantities, <1 to 2%. Chrysotile and amosite were found either in combination or singly in these materials. Crocidolite was found with amosite, but never alone. Table II shows the number of samples that contained the different forms and combinations of asbestos. Twelve of the 56 positive samples were from sprayed materials.

Thirty-one of the 41 schools surveyed had asbestos-containing materials in one or more locations. Of those 31, 10 schools had sprayed-on asbestos ceilings. Table III shows the number of schools in each region that had asbestos-containing materials and/or sprayed surfaces.

Based on the number of schools found to have asbestos-containing materials in the random sample, it was estimated that between 63% and 89% (95% confidence interval) of the public schools in Colorado may have friable asbestos-containing materials. Ten percent to 38% (95% confidence interval) of Colorado schools may have sprayed-on materials which contain asbestos.

Table II. Asbestos-Containing Samples by Type of Asbestos

Type	Number of Samples								
	Sprayed				Other				
	1-10%*	11-25%	26-50%	>51%	1-10%	11-25%	26-50%	>51%	Total
Chrysotile	8	--	--	--	5	--	10	14	39
Amosite	--	--	--	--	3	--	1	--	4
Chrysotile-actinolite	2	--	--	--	--	--	--	--	2
Chrysotile-amosite	--	--	--	--	4	2	2	1	9
Amosite-crocidolite	--	--	--	--	--	--	--	2	2
TOTAL	10	0	2	0	12	2	13	17	56

*Percentage ranges used in the "evaluation of potential asbestos exposure"

Table III. Schools Containing Asbestos by Region

Region	Number of Schools Sampled	Number of Schools With Asbestos	Number of Schools With Sprayed-on Asbestos
I	23	16 (70%)	7 (30%)
II	3	2 (67%)	0
III	6	5 (83%)	2 (33%)
IV	4	4 (100%)	1 (25%)
V	5	4 (80%)	0
TOTAL	41	31 (76%)	10 (24%)

Using data obtained from the Colorado Department of Education (for about 70% of the schools in the state), schools were stratified by age of construction into three groups: pre-1946, 1946-1973 and post-1973. Moreover, a majority of the schools had undergone one or more additions or renovations. When the information on the age(s) of additional construction was combined with the age of original construction for these buildings several subcategories within the three original strata resulted. The resultant strata and the number of schools in each are presented in Table IV. For the first category of original construction it was conceivable that all three periods of construction could be found in the same school. This is represented by the "Combination" sub-category. Because the number of schools which could be surveyed was small, choosing a random sample from among all these categories was extremely difficult. Therefore, a simple random sample was chosen.

A post-stratification of the selected schools into these categories indicated that the simple random sample achieved the desired result of including buildings of all ages of construction in the study.

Table IV. Stratification of Schools by Age of Construction

Age of Construction		Number of Schools	
Original	Additional*	Statewide	Surveyed
Pre-1946	None	36	5
	Pre-1946	19	2
	1946-1973	72	4
	Post-1973	6	0
	Combination	39	4
1946-1973	None	211	8
	1946-1973	222	4
	Post-1973	60	5
	Combination	59	5
Post-1973		77	4
		801**	41

*Additions and remodelling
**Information available for 801 of 1,263 schools in the state

Stratification into age of construction by area sampled is presented in Table V. The samples are also separated by whether or not the material was sprayed on. All samples of sprayed-on materials were taken from the 1946-1973 period. Of the other materials, only 9% were from post-1973 construction. Forty-one percent of the samples were from building areas constructed prior to 1946, while 50% of the samples represented construction in the 1946-1973 period.

Table V. Age of Construction of Areas From Which Asbestos-Containing Samples Were Obtained

Age of Construction	Material		Total
	Sprayed	Other	
Pre-1946	0	18	18
1946-1973	12	22	34
Post-1973	0	4	4
TOTAL	12	44	56

In Table VI, stratification by grade level is shown. With the exception of the one school in the "Other" category, the proportions of schools from each grade level are very similar. The proportions of schools sampled at each grade level that contain asbestos materials are also very similar.

Table VI. Stratification by Grade Level

Grade Level	Number in State	Number Sampled	Number With Asbestos	Number With Sprayed-on Asbestos
Elementary	733	25 (3.4%)	18 (73%)	5 (2%)
Junior High	212	7 (3.3%)	5 (71%)	0
Senior High	253	8 (3.2%)	7 (87%)	4 (50%)
Other	65	1 (1.5%)	1	1

In evaluating sample sites for the potential for asbestos exposure to occur, each category (activity, accessibility, condition, friability, air movement and percent asbestos) was

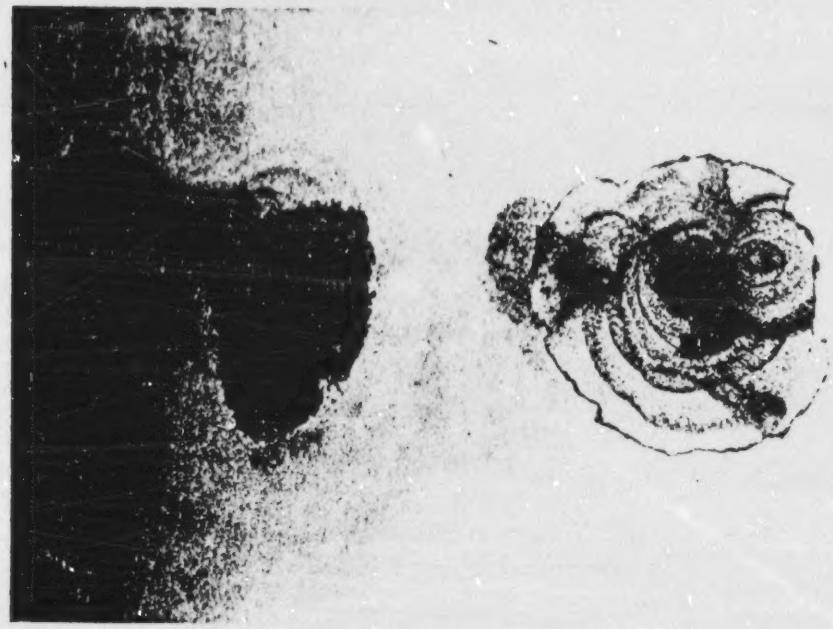
assigned a value which indicated the effect of that category on the overall value. These values and the exposure potentials they represent are shown in Table VII. The lower numbers represented lower exposure potentials. Activity was broken down into areas of low activity (i.e., offices, boiler rooms and storage areas), moderate activity (classrooms) and high activity (gymnasiums, hallways and all-purpose rooms). For accessibility, materials were identified as totally enclosed or tightly bound, generally inaccessible to the school population or accessible. The condition of the materials from which a sample was taken was evaluated as having no damage at all, slight to moderate damage or severe damage. Examples of severe damage are shown in Figures 2 and 3 where sprayed materials have been damaged by water and by contact, respectively. Materials were classified as either moderately friable (i.e., ceiling tiles, cementitious materials) or very friable (sprayed materials). No samples were taken of nonfriable substances. In each area from which a sample was taken, it was determined if a mechanical air moving system was present, if only limited air movement was possible (open doors and windows, for instance) or if there was essentially no air movement in the area. When the results of the polarized light microscopy were received from the laboratory, the percent asbestos in the sample was added to the evaluation. Four categories were used: 1-10%, 11-25%, 26-50% and >51%. The values determined for each of these categories were added for each sample which contained

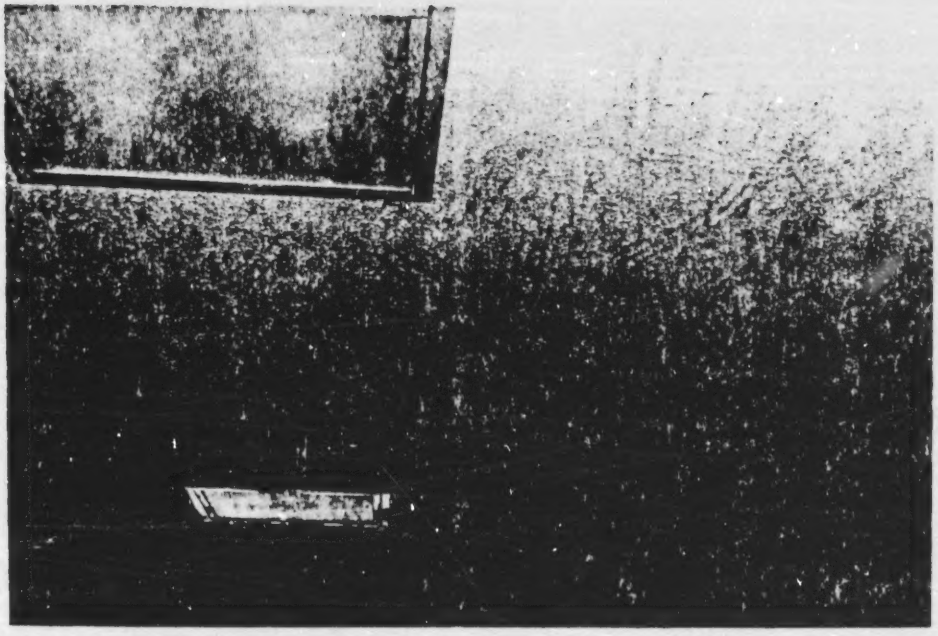
Table VII. Evaluation Aid for Assessing Potential Asbestos Exposure

Category	Numerical Value	Evaluation
Activity	1	Low
	2	Moderate
	3	High
Accessibility	1	Totally Enclosed
	2	Generally Inaccessible
	3	Accessible
Condition	1	No Damage
	2	Slight to Moderate Damage
	3	Severe Damage
Friability	1	Nonfriable
	2	Moderately Friable
	3	Very Friable
Air Movement	1	Air Moving System Exhausted to Exterior
	2	Limited Air Movement
	3	No Air Movement
Percent Asbestos	1	1-10%
	2	11-25%
	3	26-50%
	4	51% or More

Figure 2. Sprayed-on asbestos material damaged by water.

Figure 3. Sprayed-on asbestos material damaged by capricious contact.





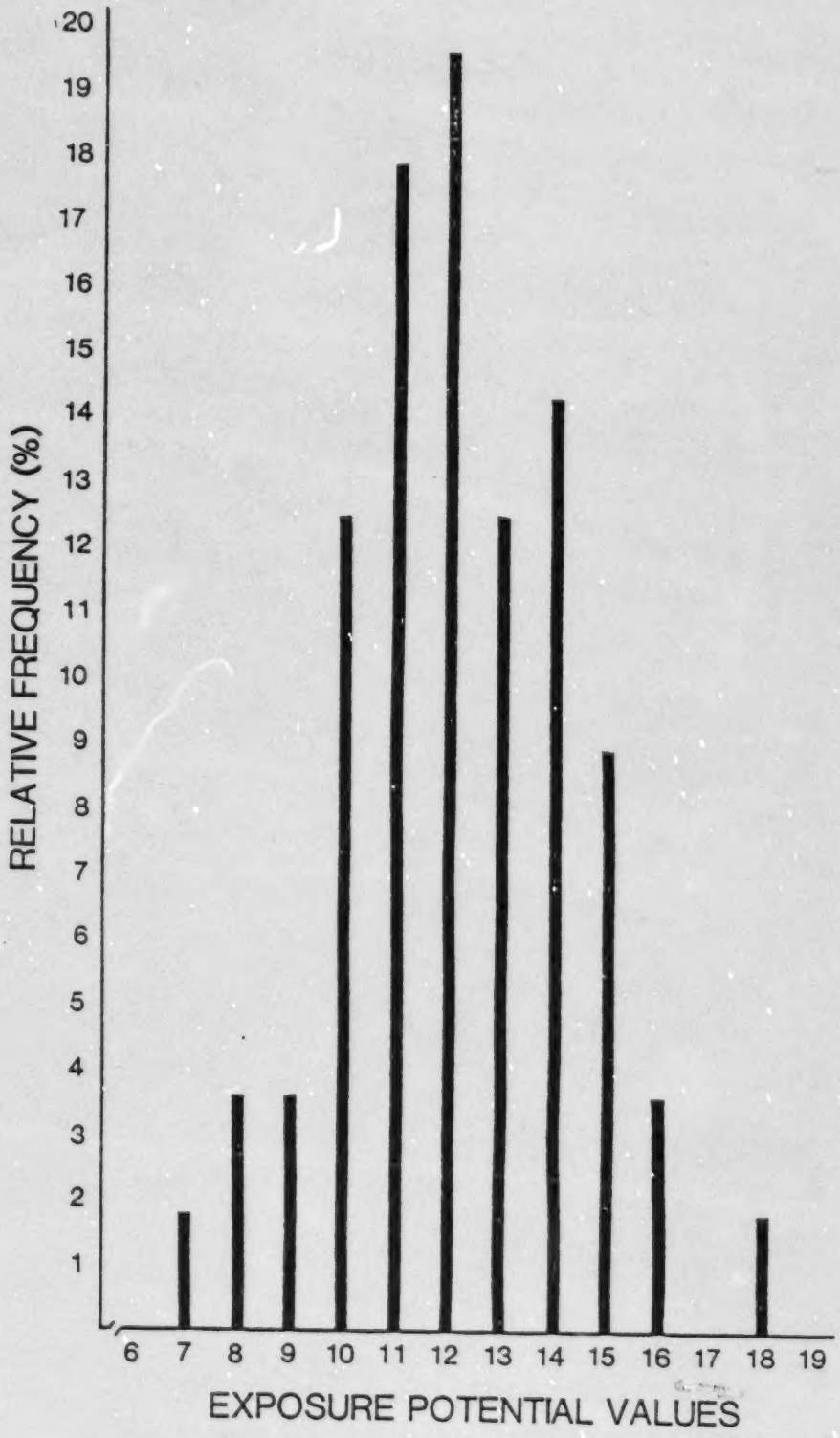
asbestos, thus yielding a total exposure potential value for each area from which a sample was taken. As an example, the exposure potential value for the area shown in Figure 3 would be calculated as follows:

Activity	3
Accessibility	3
Condition	3
Friability	3
Ventilation	1
Percent asbestos	2
TOTAL	15

This area was a hallway so the activity level was high. The celing could be reached by the students by jumping so the value for accessibility is high also. The surface of the material has been badly scored and the material was very friable. The school did have a mechanical air moving system which exhausted air to the exterior of the building so presumably loose asbestos fibers would not accumulate in the building. Analysis of the bulk sample indicated that the sample contained <1-2% actinolite and 15% chrysotile. The total value was 15. An expanded guide to the evaluation of potential exposure to asbestos is included in Appendix A.

The values calculated for the areas where asbestos was found ranged from seven to 18. The relative frequencies of each exposure potential value for all 56 samples are shown in Figure 4. If a potential exposure value from six to

Figure 4. Exposure Potential Values of Areas with Asbestos-Containing Materials in Selected Colorado Schools


RELATIVE FREQUENCY (%)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
6 7 8 9 10 11 12 13 14 15 16 17 18 19
EXPOSURE POTENTIAL VALUES

eight would indicate that no action need be taken, while one from nine to 19 indicated that some corrective action was required, the calculated potential exposure values would indicate that action is required in 53 (95%) of the areas sampled in this study. It must be noted, however, that the decision to choose to apply some method of control should be carefully considered for each specific situation. Further, the method of control selected (removal, encapsulation or enclosure) must be appropriate for the type of material involved and its location. It is also important that the corrective action chosen be properly done or a more serious problem could be the result.

Despite the fact that the consequences of exposure to airborne asbestos fibers in schools are not known, it cannot be denied that the possibility of such exposures occuring is considerable. The accumulation of evidence that indicates that low levels of asbestos fibers can cause neoplastic disease suggests that the presence of friable asbestos-containing materials in school buildings may present a serious hazard involving a large segment of the population. In just the 41 schools surveyed in Colorado, there were nearly 19,000 students and 2,000 full- and part-time faculty and staff members. Compounding the problem even further is the fact that many school buildings are used for extracurricular activities by students and for community functions. Thirty-five of the schools surveyed were used after regular school hours by students and the community

and three-fourths of these schools contained friable asbestos materials. All of these factors are indicative of the need for knowledge about asbestos-containing materials. It is important that school administrators be aware of the potential hazards and know where asbestos-containing substances may be found in their schools. Once the substances are located, each specific area should be dealt with in a manner which will reduce the hazard of potential exposures to students, faculty and/or staff. In addition, if the asbestos-containing materials are left in place, it is important that records be kept regarding their locations to avoid mishandling of the materials during future maintenance, remodelling or demolition activities.

CHAPTER 6

SUMMARY

Asbestos-containing products were extensively used in building construction for decades. The consistency of these materials ranges from very friable to nonfriable and they may be found in a variety of areas.

The fact that exposure to low levels of airborne asbestos fibers can result in diseases such as lung cancer and mesothelioma has generated an increasing concern over the presence of friable, asbestos-containing materials in public buildings, especially schools. The primary concern is that these materials may release asbestos fibers into school environments through natural aging, accidental or capricious contact, or damage by other means such as normal maintenance, lack of maintenance and water damage. Children, because they are very active, have rapid growth rates and frequently breathe through their mouths (resulting in less effective natural filtering), may be especially susceptible to the adverse effects of asbestos, but faculty and staff members in school buildings are at risk as well. The extent to which asbestos-containing materials were used in the nation's schools is not yet known, but studies done in some states have revealed that there are considerable amounts of these materials present.

The intent of this study was to determine how extensively asbestos-containing materials were used in Colorado

by surveying a random sample of schools. Where possible asbestos-containing materials were found, samples of the suspect materials were obtained, their condition was evaluated and an estimate made of the potential for fiber release. The criteria evaluated to assess the potential for asbestos exposure included activity level in the area, accessibility, condition and friability of the materials, and the amount of air movement in the area. After laboratory analysis of the samples, the percent of asbestos in the material was added to the evaluation.

A preliminary screening of the bulk samples using the K^2 Asbestos Screening Test identified only 10.6% of the samples as not containing asbestos. Because of the low number of samples which were negative (possibly due at least in part to difficulties in interpreting results), and problems with use in the field, the K^2 Test is not recommended for use by school personnel. Samples of suspect materials should be sent to accredited laboratories for analysis by polarized light microscopy with x-ray diffraction if necessary.

Twelve of the samples which contained asbestos were from sprayed-on materials. Chrysotile was found in all these samples and some contained actinolite as well. Chrysotile and amosite were the primary forms of asbestos found in other substances, but some contained crocidolite in small amounts as well. Crocidolite is thought to be more frequently associated with the development of mesothelioma than the other types of asbestos.[1]

Of the 41 schools surveyed, 31 (76%) had asbestos-containing materials in one or more locations. Ten of these schools (24%) had sprayed asbestos-containing materials on the ceilings. Based on these figures, between 63% and 89% of the public schools in Colorado may contain friable asbestos-containing substances. From 10% to 38% of the schools in the state may have sprayed materials containing asbestos. Most of the schools in the state were built from 1946 to 1973 when building materials containing asbestos, especially in sprayed form, were frequently used. The majority of the samples containing asbestos were taken from areas built during that period, and all of the samples of sprayed materials were from that time frame. Asbestos-containing materials were found in buildings serving all grade levels indicating that exposure to asbestos could conceivably occur throughout the entire period of time that a child is in school.

The actual levels of asbestos to which individuals could be exposed would vary quite widely with varying conditions, but the potential risk of exposure may be assessed using the evaluation scheme developed for this study. The evaluation is designed *only* to help assess the *potential* for exposure to occur. It *does not* attempt to correlate the potential exposure to the actual levels of fibers that might be in the air, nor to the possible effects that might result from the exposure. The numerical value that results may be used in conjunction with advice from an expert

skilled in dealing with asbestos-containing materials to determine the most appropriate procedure for dealing with the situation. Grouping of lower scores into a "defer action" category and high scores into a "corrective action" category is *not* recommended because some action is necessary in any case where asbestos-containing materials exist, even if that action is simply to review the condition of the material periodically. The evaluation of potential asbestos exposure represents the potential exposure risk only at the time when the evaluation was completed. The value for any one of the categories might change at any time, changing the overall potential for exposure. Interpretation of the total value should simply be that lower values indicate lower potentials for exposure while higher values represent greater exposure potentials. If is *most* important that each situation be considered and treated individually. For situations in which the exposure potential initially is low, management may be the appropriate course of action. For instance, access to an area might be strictly limited, signs indicating the nature of the material might be posted and a reevaluation of the potential exposure should be completed at suitable intervals, perhaps yearly. A more serious situation might require enclosure, encapsulation or even removal of the material. For this study, results were simply reported to school officials, no recommendations on action were made.

It is important for school officials, teachers and staff of the schools and parents of children to be aware of the presence of asbestos-containing materials in schools. Records concerning the locations of these materials in each school should be maintained by the school and referred to when building renovations or additions are considered. Maintenance and janitorial personnel need to know where asbestos-containing materials are located and how to handle them if it becomes necessary. Once school administrators have identified asbestos-containing materials and developed a plan for dealing with them, the parents of children in the school should be made aware of the situation and how it will be dealt with to avaoid misunderstandings and hysteria.

The results of this study indicate that the presence of friable asbestos materials in Colorado's public schools is common. It is possible that as many as 1,124 (89%) of the 1,263 schools in Colorado may contain asbestos in friable form. Four hundred and eighty (38%) of the schools may have sprayed asbestos on ceilings. If the exposure potential values found for the small number of schools surveyed are typical of values which might be found in other schools in the state, a very serious problem exists. The situation is serious not only because of possible adverse health effects which may occur in the future but also because the cost of dealing with asbestos-containing material may be quite high and, if the proper

procedures are not followed, the severity of the problem will be compounded. The expense of dealing with these substances should not be an excuse for ignoring the situation, however. Simply identifying these materials is an enormous step in the right direction and it is strongly recommended that this step be taken for the remainder of the public schools in the state as well as the private schools.

LITERATURE CITED

1. Selikoff, Irving J. and Douglas H. K. Lee: *Asbestos and Disease.* Academic Press, Inc., New York (1978).

2. Peters, George A. and Barbara J. Peters: *Sourcebook on Asbestos Diseases: Medical, Legal and Engineering Aspects.* Garland STPM Press, New York (1980).

3. *Asbestos: An Information Resource.* Richard J. Levine (ed.). DHEW Publication Number (NIH) 78-1681 (1978).

4. Figlio, Mary Ellen: Asbestos: No Easy Solutions. *Am. Sch. and Univ. 52*(2):46-50 (1979).

5. Robison, Rita: Asbestos: What You Can Do About It. *Am. Sch. and Univ. 51*(9):48-55 (1979).

6. Levin, Dan: Asbestos in Schools: Walls and Halls of Troubles. *Am. Sch. Board J. 165*(11):29-32 (1978).

7. Rom, William N. and Philip E. S. Palmer: The Spectrum of Asbestos-Related Diseases. *West. J. Med. 121*:10-21 (1974).

8. LaFleur, Philip D.: Foreword. IN *Workshop on Asbestos: Definitions and Measurement Methods.* C. C. Gravatt, Philip D. LaFleur and Kurt F. J. Heinrich (eds.). National Bureau of Standards Special Publication 506 (1978).

9. Spooner, Charles M.: Asbestos in Schools. A Public Health Problem. *N. Engl. J. Med. 301*:782-784 (1979).

10. Sawyer, Robert N. and Charles M. Spooner: *Sprayed Asbestos-Containing Materials in School Buildings: A Guidance Document. Part 2.* U.S. Environmental Protection Agency Publication #EPA-4501 2-78-014.

11. *Friable Asbestos-Containing Materials in Schools: Proposed Identification and Notification.* Environmental Protection Agency. 40 CFR Part 763. *Fed. Reg. 45*(182): 61966-61997 (1980).

12. *Asbestos-Containing Materials in School Buildings: A Guidance Document. Part 1.* U.S. Environmental Protection Agency, Office of Toxic Substances, Washington, D.C. (1979).

13. Kleinfeld, Morris: Biologic Response to Kind and Amount of Asbestos. *J. Occup. Med.* *15*:296-300 (1973).

14. Selikoff, I. J., E. C. Hammond and J. Churg: Asbestos Exposure, Smoking and Neoplasia. *J. Am. Med. Assoc.* *204*:106-112 (1968).

15. Michaels, Leslie and Seymour S. Chissick: Introduction. IN *Asbestos. Volume I. Properties, Applications and Hazards.* Leslie Michaels and Seymour S. Chissick (eds.). John Wiley and Sons, Belfast (1979).

16. Buchanan, William D.: Asbestos-Related Diseases. Part I: Introduction. IN *Asbestos. Volume I. Properties, Applications and Hazards.* Leslie Michaels and Seymour S. Chissick (eds.). John Wiley and Sons, Belfast (1979).

17. Greenberg, Morris and T. A. Lloyd Davies: Mesothelioma Register, 1967-68. *Br. J. Ind. Med.* *31*:91-104 (1974).

18. McDonald, J. C., G. W. Gibbs, J. Manfreda and F. M. White: Storage as a Factor in Disease Due to Mineral Dusts. IN *Multiple Factors in the Causation of Environmentally Induced Disease.* Douglas H. K. Lee and Paul Kotin (eds.). Academic Press, Inc., New York (1972).

19. Wagner, J. C.: Epidemiology of Diffuse Mesothelial Tumors: Evidence from Studies in South Africa and the United Kingdom. *Ann. N. Y. Acad. Sci.* *132*:575-578 (1965).

20. Becklake, Margaret R.: Asbestos-Related Diseases of the Lung and Other Organs: Their Epidemiology and Implications for Clinical Practice. *Am. Rev. Respir. Dis.* *114*:187-227 (1976).

21. Li, Frederick P., Jacob Lokich, Janet Lepey, Wilford B. Neptune and Earle W. Wilkins, Jr.: Familial Mesothelioma After Intense Asbestos Exposure at Home. *J. Am. Med. Assoc.* *240*:467 (1978).

22. Vianna, Nicholas J. and Adele K. Polan: Non-occupational Exposure to Asbestos and Malignant Mesotheliomas in Females. *Lancet* *1*:1061-1063 (1978).

23. Newhouse, Muriel L. and Hilda Thompson: Epidemiology of Mesothelial Tumors in the London Area. *Ann. N. Y. Acad. Sci.* *132*:579-588 (1965).

24. Lieben, Jan and Harry Pistawka: Mesothelioma and Asbestos Exposure. *Arch. Environ. Health* *14*:559-563 (1967).

25. Anderson, Henry A., Ruth Lilis, Susan M. Daum, Alf S. Fischbein and Irving J. Selikoff: Household Contact Asbestos Neoplastic Risk. *Ann. N. Y. Acad. Sci. 271*: 311-323 (1976).

26. Suta, Benjamin E. and Richard J. Levine: Non-occupational Asbestos Emissions and Exposures. IN *Asbestos. Volume I. Properties, Applications and Hazards.* Leslie Michaels and Seymour S. Chissick (eds.). John Wiley and Sons, Belfast (1979).

27. Hueper, W. C.: Occupational and Nonoccupational Exposures to Asbestos. *Ann. N. Y. Acad. Sci. 132*:184-195 (1965).

28. Arul, K. J. and P. F. Holt: Mesothelioma Possibly Due to Environmental Exposure to Asbestos in Childhood. *Int. Arch. Occup. Environ. Health 40*:141-143 (1977).

29. Wagner, J. C., C. A. Sleggs and Paul Marchand: Diffuse Pleural Mesothelioma and Asbestos Exposure in the North Western Cape Province. *Br. J. Ind. Med. 17*:260-271 (1960).

30. Collins, T. F. B.: Asbestos - The Lethal Dust. *S. Afr. Med. J. 41*:639-646 (1947).

31. Bates, David V.: Community Air Pollution in Canada: A Review and Predictions for the 1980s. *Can. Med. Assoc. J. 120*:1252-1256 (1979).

32. Thériault, Gilles P. and Liliane Grand-Bois: Mesothelioma and Asbestos in the Province of Quebec, 1969-1972. *Arch. Environ. Health 33*:15-19 (1978).

33. Brodeur, Paul: *The Asbestos Hazard.* The New York Academy of Sciences, New York (1980).

34. Nicholson, William J., Arthur M. Langer and Irving J. Selikoff: Epidemiological Evidence on Asbestos. IN *Workshop on Asbestos: Definitions and Measurement Methods.* C. C. Gravatt, Philip D. LaFleur and Kurt F. J. Heinrich (eds.). National Bureau of Standards Special Publication 506 (1978).

35. Chen, Wei-jen and N. Karle Mottet: Malignant Mesothelioma with Minimal Asbestos Exposure. *Hum. Pathol. 9*: 253-258 (1978).

36. *Biologic Effects of Atmospheric Pollutants. Asbestos. The Need For and Feasibility of Air Pollution Controls.* Committee on Biological Effects of Atmospheric Pollutants, Division of Medical Sciences, National Research Council. National Academy of Sciences, Washington, D.C. (1971).

37. Kiviluoto, Raimo: Pleural Plaques and Asbestos: Further Observations on Endemic and Other Nonoccupational Asbestosis. *Ann. N. Y. Acad. Sci.* *132*:235-239 (1965).

38. Kiviluoto, Raimo: Pleural Calcification as a Roentgenologic Sign of Non-occupational Endemic Anthophyllite-Asbestosis. *Acta Radiol. Suppl.* *194*: 1-67 (1960).

39. Selikoff, I. J.: Cancer Risk of Asbestos Exposure. IN *Origins of Human Cancer. Book C. Human Risk Assessment.* H. H. Hiatt, J. D. Watson and J. A. Winsten (eds.). Cold Spring Harbor Laboratory (1977).

40. Thomson, J. G., F. C. Path and Wallace M. Graves, Jr.: Asbestos as an Urban Air Contaminant. *Arch. Pathol.* *81*:458-464 (1968).

41. Thomson, J. G.: Asbestos and the Urban Dweller. *Ann. N. Y. Acad. Sci.* *132*:196-214 (1965).

42. Selikoff, Irving J., William J. Nicholson and Arthur M. Langer; Asbestos Air Pollution. *Arch. Environ. Health* *25*:1-13 (1972).

43. Warnock, Martha L. and Andrew M. Churg: Association of Asbestos and Bronchogenic Carcinoma in a Population with Low Asbestos Exposure. *Cancer* *35*:1236-1242 (1975).

44. Whitwell, F., Jean Scott and Myra Grimshaw: Relationship Between Occupations and Asbestos-Fibre Content of the Lungs in Patients with Pleural Mesothelioma, Lung Cancer and Other Diseases. *Thorax* *32*:377-386 (1977).

45. Cooper, W. Clark: Epidemiologic Evidence of the Effect of Type of Asbestos and Fiber Dimensions on the Production of Disease in Man. IN *Workshop on Asbestos: Definitions and Measurement Methods.* C. C. Gravatt, Philip D. LaFleur and Kurt F. J. Heinrich (eds.). National Bureau of Standards Special Publication 506 (1978).

46. Lowrey, George H.: *Growth and Development of Children.* Year Book Medical Publishers, Inc., Chicago (1973).

47. Knelson, J. H.: Problem of Estimating Respiratory Lead Dose in Children. *Environ. Health Perspect.* *7*:53-57 (1974).

48. Silver, Kenneth Z.: Asbestos in School Buildings: Results of a Nationwide Survey. *Ann. N. Y. Acad. Sci.* *330*:777-786 (1979).

49. Kane, Dorothy Noyes: Bad Air for Children. *Environment 18*:26-34 (1976).

50. Sawyer, Robert N. and Edward J. Swoszowski, Jr.: Asbestos Abatement in Schools: Observations and Experiences. *Ann. N. Y. Acad. Sci. 330*:765-775 (1979).

51. Sawyer, Robert N.: Asbestos Exposure in a Yale Building. Analysis and Resolution. *Environ. Res. 13*:146-169 (1977).

52. Nicholson, William J., Edward J. Swoszowski, Jr., Arthur N. Rohl, James D. Todaro and Antoinette Adams: Asbestos Contamination in United States Schools from Use of Asbestos Surfacing Materials. *Ann. N. Y. Acad. Sci. 330*:587-596 (1979).

53. Faich, Gerald A.: Asbestos Hazard Evaluation in Rhode Island Schools. *Am. J. Public Health 70*:162-164 (1980).

54. Irving, Karen F., Rexford G. Alexander and Harold Bavley: Asbestos Exposures in Massachusetts Public Schools. *Am. Ind. Hyg. Assoc. J. 41*:270-276 (1980).

55. Kim, Walter S., James W. Carter, II and Richard E. Kupel: Quick Screening Test for Asbestos. *Am. Ind. Hyg. Assoc. J. 42*:198-201 (1981).

APPENDIX A

SAMPLE COLLECTION DATA

SCHOOL DISTRICT _____ DATE _____

SCHOOL _____

TYPE OF ROOM/AREA _____

DATE OF CONSTRUCTION _____

( ) original ( ) add-on ( ) remodel

SAMPLE ID# _____

DESCRIPTION _____

_____

_____

LOCATION _____

_____

_____

ACTIVITY ____
ACCESSIBILITY ____
CONDITION ____
FRIABILITY ____
VENTILATION ____
% ASBESTOS ____

TOTAL ____

SAMPLE ID# _____

DESCRIPTION _____

_____

_____

LOCATION _____

_____

_____

ACTIVITY ____
ACCESSIBILITY ____
CONDITION ____
FRIABILITY ____
VENTILATION ____
% ASBESTOS ____

TOTAL ____

NOTES

GENERAL DATA

Date _____

ADDRESS

School Name _____

District _____

Address _____

_____

GRADE LEVELS SERVED _____

SCHOOL POPULATION

Number of pupils _____

Number of teachers and staff - full-time _____

part-time _____

BUILDING USE

A. Standard Curricular Use (regular classes)
   -Days per year _____
   -Teacher and staff attendance hours per day _____
   -Pupil attendance hours per day _____

B. Extracurricular Use (teacher/staff supervised)
   -Days per year _____
   -Supervisor attendance hours per day _____
   -Pupil attendance hours per day _____

C. Community and Other Use
   -Days per year _____
   -Hours per day _____
   -Number of people _____

BUILDING CONSTRUCTION

A. Original construction
   -Date(s) _____
   -Contractor _____
   (name and address)

GENERAL DATA - 2

A. Original construction (continued)

-Architect _____
(company name)

_____
(address)

-Description _____

_____

_____

_____

_____

B. Additions

1. -Date(s) _____

-Contractor _____
(company name)

_____
(address)

-Architect _____
(company name)

_____
(address)

-Description _____

_____

_____

2. -Date(s) _____

-Contractor _____
(company name)

_____
(address)

-Architect _____
(company name)

_____
(address)

-Description _____

_____

_____

GENERAL DATA - 3

D. Remodelling

1. -Date(s) _____

-Contractor _____
(company name)

_____
(address)

-Architect _____
(company name)

_____
(address)

-Description _____

_____

_____

2. -Date(s) _____

-Contractor _____
(company name)

_____
(address)

-Architect _____
(company name)

_____
(address)

-Description _____

_____

_____

AN EVALUATION AID IN ASSESSING POTENTIAL ASBESTOS EXPOSURE

NOTE OF CAUTION: This evaluation aid is presented to provide general guidance. If there is any question regarding the potential for asbestos exposure of students and other building users, professional consultation is necessary.

Directions for use:

1. For each of the six factors, circle the most appropriate numerical value (circle only one number per factor) or record on the "Sample Collection Data" form.
2. Add up all of the circled numbers, and refer to the "Action Suggestions."

Note: the minimum total value is six (6) and the maximum total value is nineteen (19).

ACTIVITY The potential, because of room use, for damage to asbestos containing material.

Numerical Value	Evaluation Category
1	Low activity areas (e.g., closets and storage rooms; conference rooms; faculty room; administration offices; nurse's office; janitor's room; boiler room)
2	Moderate activity areas (e.g., locker room; music room; cooking, sewing and typing rooms; science rooms; shops; general classrooms; kitchen)
3	High activity areas (e.g., gymnasium; auditorium, cafeteria, hallways and stairways; swimming pool, all purpose rooms)

EVALUATION OF POTENTIAL ASBESTOS EXPOSURE - 2

ACCESSIBILITY The relative ease with which the asbestos-containing material may be reached or disturbed.

Numerical Value	Evaluation Category
1	Totally enclosed, encapsulated or tightly bound (e.g., pipe lagging behind enclosed radiators; floor tiles unless scored or sanded)
2	Generally inaccessible to school population (e.g., ceiling tiles and sprayed surfaces beyond normal hand reach or potential damage from thrown objects; pipe lagging in locked closet)
3	Accessible (e.g., pipe lagging, ceiling surfaces, etc., within hand reach or subject to damage from thrown objects-gymnasium, hallway, classroom ceilings)

CONDITION The degree of deterioration and damage of asbestos-containing materials.

Numerical Value	Evaluation Category
1	No damage at all.
2	Slight to moderate damage (e.g., small chips missing from ceiling tiles; mild water stains on ceilings; loose pipe wrapping)
3	Severe damage (e.g., scored or punctured pipe lagging, loosely hanging material, severe water damage)

EVALUATION OF POTENTIAL ASBESTOS EXPOSURE - 3

FRIABILITY The ease with which the asbestos-containing material may be broken or crumbled.

Numerical Value	Evaluation Category
1	Nonfriable (i.e., asbestos fibers firmly bound as in some floor tiles and pipes; material cannot be broken or fractured with hands)
2	Moderately friable (i.e., material may be broken or fractured, but breaks up into relatively large pieces)
3	Very friable (i.e., material is easily broken apart with hands and easily crumbled with fingers)

AIR MOVEMENT The degree to which asbestos fibers may accumulate in the area of the sampling site.

Numerical Value	Evaluation Category
1	Presence of mechanical air moving system which exhausts air to building exterior
2	Limited air movement (i.e., open doors and windows, ceiling fan)
3	Essentially no air movement

EVALUATION OF POTENTIAL ASBESTOS EXPOSURE - 4

PERCENT ASBESTOS The amount of asbestos contained in the material. (NOTE: This will be indicated on the laboratory analysis report.)

Numerical Value	Evaluation Category
1	One to 10 percent
2	Eleven to 25 percent
3	Twenty-six to 50 percent
4	Fifty-one percent or more

☐ Total numerical value (add up the circled numbers

ACTION SUGGESTIONS:

In general, the lower the total numerical value that results from the above assessment, the lower is the risk that exposure to asbestos fibers may occur. Likewise, higher values represent higher exposure potentials. There are four ways of dealing with asbestos-containing materials: management, enclosure, encapsulation and removal. This exposure potential value should be used together with expert advice to determine what action is appropriate in each situation.